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# Method for making ceramic artificial dental bridges

The present invention relates to a method for making artificial dental bridges accurate to shape in high strength ceramic materials, by joining of two or more ceramic parts to each other. The ceramic parts for such a joining could be manufactured using a technique as described in US 5,342,201.

The object of the present invention is to achieve a rational manufacturing technique for dental bridges in densely sintered high strength ceramic material using modern powder metallurgical technique, registering technique, and joining technique. Dental bridges in i.e. densely sintered high strength alumina offer a combination of mechanical strength and esthetics, which is not possible with established dental materials and methods, intended for dental bridges.

The present invention relates to a method of manufacturing artificial dental bridges in densely sintered ceramic material by joining two or more densely sintered ceramic parts with the aid of a particle reinforced glass in a ONE step heating process. The individual parts, whose inner surface which should fit against one or more prepared tooth surfaces or artificial abutments, are made by forming a ceramic powder mixture against a surface of a body whereby said surface is made using a three-dimensional optical or mechanical reading method in which the surfaces of the prepared teeth or artificial abutments and their mutual relationship are registered, either directly in the mouth or on a model in e.g. plaster whereafter the registered surfaces are reproduced in an enlarged format e.g. with the aid of a computer controlled milling machine whereby the magnification is calculated considering the shrinkage of the ceramic material during sintering to full density with addition of desired gap required for cement according to US 5,342,201 and US 5,080,589.

Fig. 1 shows a cross section of a natural tooth with an artificial tooth crown. In this figure, A= dental porcelain, B= core, Y= outer surface of the core, I= inner surface of the core, C= cement, P= prepared surface of the tooth, S= preparation border, E= enamel, D= dentin and F= pulp.

Fig. 2 shows a cross-section of a bridge containing three joined parts. The bridge is cemented on two supporting teeth. These supporting teeth may have a vital abutment (U1) or an

artificial abutment (U2) manufactured in some dental alloy, ceramic material or some reinforced polymer. The bridge contains two artificial tooth crowns according to Fig. 1 and with a central pontic (V), as a substitute for a lost tooth. The joining of the parts is accomplished in the following manner:

1) A premixed suspension of particles, dispersant for the particles, binder for the particles, and solvent (e.g. water) is applied between the parts and allowed to dry.

2) A suspension of glass material and solvent (e.g. water) is then applied to the newly formed joint of particles.

3) The bridge is then heated to a sufficient temperature and for a sufficient time so that the glass material melts and penetrated completely through the joint.

The glass material fully wets the surface of the densely sintered parts forcing the particles away from the surface. The glass will also wet the surface of each of the individual particles such that the final joint will be pure glass on the surface of the densely sintered parts and a particle reinforced glass (i.e. non-touching particles) a short distance away from the surface. Since no particles are in contact with the surface of the densely sintered parts the material binding the parts together is the glass and the particles act to only increase the strength of the glass material.

The present invention offers two significant advantages over the invention disclosed in WO 99/13795 in which only glass is used to create a joint between the various bridge parts. The first is that prior to heat treatment the dried particle network gives sufficient strength to the bridge so that it can be easily transported to a heating device without the need of a support structure and the second is that the particle reinforced glass has a higher resistance to cracking (i.e. higher  $K_c$ ) than the pure glass material.

WO 01/70128 describes a TWO step process for connecting densely sintered parts. Similar to the present invention, the first step of WO 01/70128 calls for a premixed suspension of particles, dispersant for the particles, binder for the particles, and solvent (e.g. water) to be applied between the three parts and allowed to dry. The bridge is then transported to a heating device and the temperature is increased to a sufficient value such that a

lightly sintered (i.e. porous network) is created. The bridge is then brought down to room temperature and glass applied to the joints and then heated to a sufficient temperature and for a sufficient time so that the glass material melts and penetrated completely through the joint. WO 01/70128 describes the final bridge as bound together by the lightly sintered (i.e. touching) particle network. Hence, the loosely sintered particle network is in contact with the surfaces of the densely sintered parts and acts as the binding agent. The glass material is used to fill the voids within the porous network and add addition reinforcement. The present invention has an advantage over WO/70128 A1 in that it involves a ONE step heating process, which saves both time and energy for the user.

The properties of the glass material should be such that it wets the densely sintered ceramic material i.e. the glass should have a lower surface energy at the temperature used during the joining process than the ceramic material in the bridge units. This ensures that the melted glass will easily spread out over the surfaces of the bridge units in order to lower their surface energy. The melted glass must have a low viscosity in order to be able to spread into in the gap between the bridge units. Furthermore, the glass should have the characteristic property that it reacts, not too little and not too much, with the ceramic material in the bridge units in order to get an optimal bond between glass and ceramic material in the joint. In order to obtain this the glass should contain the same metal oxides as the material in the densely sintered bridge parts. This amount should be less than saturation level of the mentioned metal oxides in the glass at the joining temperature. Its thermal expansion coefficient must be lower than or equal to the ceramic material in the bridge units in order to avoid development of fractures during cooling. The joint should be designed so that a certain mechanical locking is obtained in the direction of the main force in order to obtain an optimal strength. If the joining process of the bridge units is made with a correct refractory replica of the base model, a correctly shaped joint and with a glass with properties according to above the joined bridge becomes very strong in compression at the same time as the fit can be optimal. An example of important main constituents in a glass composition that works well when joining highly pure alumina is:  $\text{SiO}_2$  32 mol%,  $\text{B}_2\text{O}_3$  24

mol%,  $\text{Al}_2\text{O}_3$  18 mol% as well as  $\text{La}_2\text{O}_3$  12 mol%. On a bridge joined with particle reinforced glass, subsequently one or more layers of dental porcelain can be burned in order to obtain good esthetics. The advantage with manufacturing bridges with the technique according to the present invention is that e.g. densely sintered high strength alumina can be joined together which results in a dental bridge with high strength, optimal fit and an esthetics which can not be obtained with conventional dental bridges of e.g. metal ceramics.

The size of the particles within the suspension should be large enough such that drying stresses do not lead to catastrophic failure of the bridge unit prior to melting and solidification of the glass material.

The densely sintered bridge parts can be made from such biocompatible oxides as  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{MgO}$ ,  $\text{ZrO}_2$  and  $\text{ZrO}_2$  with additives of smaller amounts of up to 10 mol%  $\text{Y}_2\text{O}_3$  or  $\text{MgO}$  (partly or completely stabilized  $\text{ZrO}_2$ ). It is important that the ceramic material is sintered to closed porosity, which for an oxide material means at least 98% of theoretical density, but in order to ensure good mechanical strength, the material should preferably have a density over 99% with densities over 99.5% giving the best strength. The following nonlimiting examples are given to illustrate the invention.

#### Example 1

A suspension of particles with the following composition, by weight, is blended as follows:

Acrylic Binder	1.6
Ammonium PolyAcrylate Dispersant	1.8
Deionized Water	12.6
Aluminum Oxide ( $d_{50}=3.5 \mu\text{m}$ )	84.0

Three aluminium oxide parts of density greater than 99.7% were manufactured using methods described in US 5,342,201 and standard uniaxial pressing techniques. These parts were positioned on a mold such that the suspension could be placed between them to form a particle joint and then allowed to dry. A glass material with the following composition, by mol, was then applied.

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	SiO <sub>2</sub>	32
	B <sub>2</sub> O <sub>3</sub>	24
	Al <sub>2</sub> O <sub>3</sub>	18
5	La <sub>2</sub> O <sub>3</sub>	12
	TiO <sub>2</sub>	14

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The unit was then removed from the mold and heated to a temperature of 1200°C for 1 hour. Figure 3 shows a micrograph of the center of the bridge joint. In the micrograph the lighter coloured material is the glass and the darker material is the aluminium oxide. Figure 3 clearly shows that the densely sintered alumina is completely wetted by the glass material. Hence, the glass material and not the alumina particles bind the two densely sintered pieces of alumina.

# CLAIMS

1. Method of making artificial dental bridges consisting of a ceramic densely sintered high strength individual core (B) with fired on porcelain (A) by powder metallurgical methods

5 c h a r a c t e r i s e d in that the individual densely sintered bridge parts are joined to a bridge core with particle reinforced glass by a ONE step heat treatment.

10 2. Method according to claim 1 c h a r a c t e r i s e d in that the core material consists of high strength ceramic material with a relative density greater than 98%.

3. Method according to claim 1 c h a r a c t e r i s e d in that the ceramic core material consists of one or more of the oxides  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{MgO}$ ,  $\text{ZrO}_2$  or  $\text{ZrO}_2$  with up to 10 mol%  $\text{Y}_2\text{O}_3$ ,  $\text{MgO}$  or  $\text{CaO}$ .

15 4. Method according to claim 1 c h a r a c t e r i s e d in that the glass being used for joining has a surface energy at the joining temperature lower than the surface energy for the densely sintered core material.

20 5. Method according to claim 1 c h a r a c t e r i s e d in that the glass contains the same metal oxides as the core material in an amount that falls below the degree of saturation of the mentioned metal oxides in the glass at the joining temperature.

25 6. Method according to claim 1 c h a r a c t e r i s e d in that the glass has a coefficient of thermal expansion which is lower than or the same as the coefficient of thermal expansion of the densely sintered core material.

7. Method according to claim 1 c h a r a c t e r i s e d in that the glass contains the following main constituents:  $\text{SiO}_2$  32 mol%,  $\text{B}_2\text{O}_3$  24 mol%,  $\text{Al}_2\text{O}_3$  18 mol% as well as  $\text{La}_2\text{O}_3$  12 mol%.

30 8. Method according to claim 1 c h a r a c t e r i s e d in that the particles within the bridge unit are large enough such that drying stresses on removal of the solvent do not lead to catastrophic failure of the bridge unit prior to melting and solidification of the glass material.

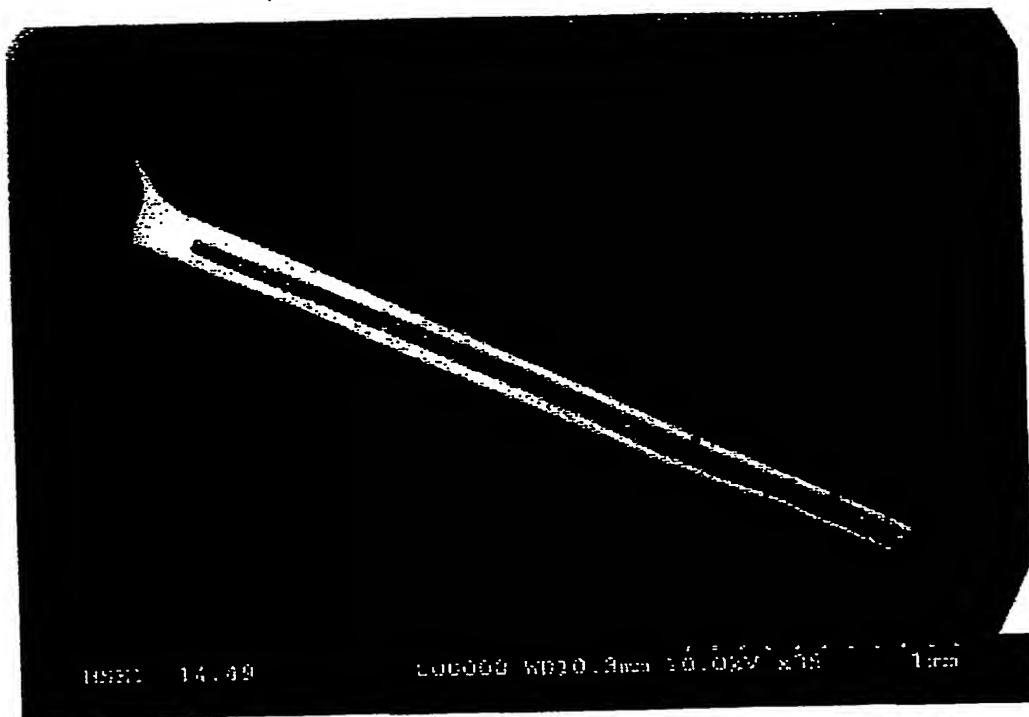
# ABSTRACT

The present invention relates to a method for making artificial tooth bridges consisting of a ceramic densely sintered high strength individual core veneered with Porcelain using powder metallurgical methods. According to the method the individual densely sintered bridge parts are joined together to a bridge core by a particle reinforced glass. Since only the glass material wets the surface of the densely sintered parts, the glass is the binding material that holds the core together and the particles function to only increase the strength (i.e.  $K_c$  value) of the bulk glass material.

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**Fig. 3**

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